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WHAT ARE THE ELASTICITY OF THE FOLLOWING ELEMENTS AT 25°C.

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aluminum, barium, beryllium, calcium, cerium, copper, cobalt, iron, the lanthanide elements, magnesium, misch metal, nickel, palladium, thorium, uranium, zinc, titanium, zirconium, hafnium, vanadium, niobium, tantalum, chromium, molybdenum, tungsten, and their suitable alloys, combinations, and mixtures. In general, any of these or other known gettering substances may be used for gettering portion 50 of emitter 30. The preferred materials for gettering portion 50 are the refractory transition metals titanium, zirconium, hafnium, vanadium, niobium, tantalum, chromium, molybdenum, tungsten, and their alloys, combinations, and mixtures (most preferably zirconium).

efunda
engineering fundamentals

Element Information: Zirconium

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Element List
by Name
by Symbol
by Atomic Number
by Atomic Weight
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OnlineMetals
Plate, angle, pipe, bar
Stainless, Aluminum
Copper, Titanium

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Zirconium

40
Zr
91.224

Atomic Number	40
Atomic Weight	91.224
Electron Config.	2-2-6-2-6-10-2-6-2-0-2

Electron configuration order: *1s-2s-2p-3s-3p-3d-4s-4p-4d-4f-5s-5p-5d-5f-6s-6p-6d-7s*

Mechanical Properties		Conditions		
		Phase	**Temp.** (K)	**Pressure** (Pa)
Density	6520 kg/m^3	Solid	298.15	0
Modulus of Elasticity	96.527 GPa	Solid	0	
Poisson Ratio	0.34	Solid		
Thermal Expansion Coefficient	5.700×10^{-6} /K	Solid	298.15	

Electrical Properties **Conditions**

		Temp. (K)	N te
Electrical Resistivity	4.000×10^{-7} Ω-m		

Thermal Properties		**Conditions**	
		Temp. (K)	**Pressure** (Pa)
Melting Temperature	2128.15 K		101325
Boiling Temperature	4682.15 K		101325
Critical Temperature	10500 K		
Fusion Enthalpy	230 J/g	0	101325
Heat Capacity	278 J/kg-K	298.15 more...	100000
Thermal Conductivity	22.7 W/m-K	300	101325

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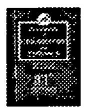
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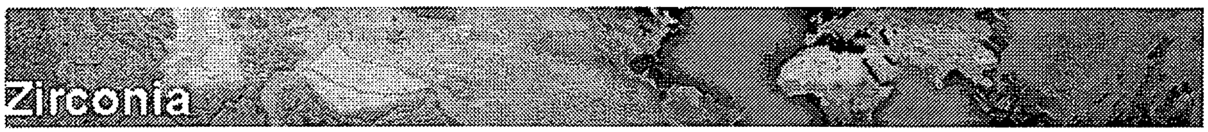
Up
Monoclinic Zirconia
PSZ Specifications



ZIRCONIA SALES (AMERICA), INC.

For over 40 years, Zirconia Sales has been a world leader in high quality precipitated and co-precipitated zirconia oxides for use in fine ceramics and biochemistry applications. This co-precipitated series of powders is ideal for functional and constructional materials. If you have special needs, we can help.

A Wide variety of precipitated and co-precipitated grades is available.

Zirconium is widely distributed in the world. It stands 20th on the Clarke numbering system, making it more common than copper, tin and zinc.

Zircon ($ZrSiO_4$) and Baddeleyite (ZrO_2) are both sources of Zirconia. These zirconia ores generally include 1-2% hafnium. It is only necessary to remove the halnium when using zironium metal in atomic energy applications.

Zirconia has excellent properties for corrosion resistance, heat resistance and low thermal conductivity. Due to its ability to form highly refractive stable glasses, it has become indispensable as a raw material for the glass industry.

Zirconia's unit-cell crystal structure, at room temperature, is monoclinic. This monoclinic structure has excellent dielectric, piez electric, and I n - c nductive properties. These properties allow Zirconia to be used in several applications, such as oxygen sensors, ignition devices, and sonar.

The monoclinic crystal structure can be stabilized and transformed to the tetragonal crystal structure at room temperature by adding vari us dopants. Because of this transformation, many new and exciting uses have been developed utilizing our Partially Stabilized Zirconia powder (PSZ). Among the physical properties, which have been utilized for these new applications, are hardness and elasticity. Some of the new applications of ur new technology are ferrules, fuel cells, and cutting tools.

We began our research in zirconium compounds forty years ago. We can assure the consistent quality of all our products because we start our manufacturing from zirconia ore bodies. We provide quality specialized zirconia compounds for all of our customers' needs.

Characteristics of Zirconium Oxide

- High melting point (about 2700°C).
- Low thermal conductivity.
- High chemical resistance (pH range from acid to alkaline).
- Low thermal expansion.
- High Kic value.
- High bending strength.
- High abrasion resistance.

- High hardness (Mohs hardness: over 7.0).

Zirconia Specs   Partially Stabilized Zirconias (PSZ) Specs

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MACHINING ZIRCONIUM

Typical Mechanical Properties:

Modulus of Elasticity (psi): 14.4×10^6
Shear Modulus (psi): 5.25×10^6
Poisson's Ratio (Ambient Temp.): 0.35
Speed of Sound Through Zr: **Long:** 1.8×10^5 in/sec
Shear Wave: .886 x 105 in/sec

Zirconium can be machined by conventional methods. Three basic parameters should be used for all machining operations:

- Slow Speeds
- Heavy Feeds
- A flood coolant system using a water soluble oil lubricant.

Zirconium exhibits a marked tendency to gall and workharden. This indicates that higher than normal clearance angles on tools are needed to penetrate the previously workhardened surface and cut a clean coarse chip. Satisfactory results can be obtained with both cemented carbide and high speed tools, however, the carbide usually gives better finishes and higher productivity. Polishing or honing the cutting edges will give the tool added life. Zirconium machines to an excellent finish, requiring relatively light horsepower compared to alloy steel. The tool forces are relatively low. Fine chips should not be allowed to accumulate on or near the machining equipment as they can easily be ignited. Zirconium can be turned readily without difficult if sharp tools and a coolant lubricant are used.

Milling:

Both vertical face and horizontal slab milling give good results. Wherever possible, zirconium should be climb milled to penetrate the work at the maximum approach angle and depth of cut while emerging through the workhardened area. The faces and edges of milling cutters should be kept very sharp. A set of herringbone cutters will permit positive axial rake angles to be effective at both sides of a recess. Optimum surface finish and tool life are obtained when the tool is ground with a positive 12° to 15° radial rake along with cutting corner. A high spiral flute should also be used. The work should be flooded or sprayed with a coolant to completely wash away all chips from the tool. The penetration can range from 0.005 to 0.010 inch per tooth at 150 to 250 SFPM. The work absorbs about 10 percent of the cutting energy with sharp cutters. Zirconium requires only about 75 percent of the horsepower required for SAE 1020 CR steel.

Grinding:

Zirconium can be specified for applications where extremely close dimensional tolerances and high quality surface finishes are required. The grinding methods used for zirconium involve standard machine equipment for all functions such as surface grinding, cylindrical grinding, centerless grinding and belt grinding. In addition, all standard abrasive equipment such as abrasive wheels, coated abrasives, and lubricants can be used. The use of straight grinding oil or oil coolant produces a better finish and higher yields as well as preventing ignition which can occur from fire, dry grinding swarf.

Wheel Grinding:

Zirconium produces a white stream of sparks. Conventional speeds and feeds are satisfactory and silicon carbide generally gives better results than aluminum oxide. At light infeeds and slow wheel speeds, higher grinding ratios are produced. At heavier infeeds and slow wheel speeds, lower grinding ratios are produced. The finishes produced are in relation to the grinding ratios. Higher grinding ratios, which mean less wheel breakdown, produce finer finishes. The effect of the grinding fluid on zirconium is the same as for other metals. Straight grinding oils produce higher grinding ratios than water miscible fluids at all infeeds.

A cylinder is generally much easier to grind than a flat surface. Cylindrical grinding of zirconium can be done with aluminum oxide wheels. The same applies to snagging. In cut-off work, silicon carbon rubber wheels prove to be most successful.

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High Performance Ceramics

August 14, 2002

ZIRCONIA

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Cerazur

Electrically insulating, good corrosion resistance, relatively low operating temperature (1000 °C), structural ceramics, good mechanical characteristics, e-module similar to steel (bonding and coatings possible), thermal expansion similar to steel, low thermal conductivity (heat insulator), very good impact resistance, good thermal shock resistance, low specific weight, anti-adhesive behaviour, low friction coefficient.

Technical Parameter

Description	Unit	Value
Material		ZrO_2 Y-PSZ
Colour		blue
Density	g/cm^3	6
Flexural Strength	MPa	1300
Compressive Strength	MPa	3000
Modulus of Elasticity (young)	GPa	205
Impact Resistance	MPa $m^{1/2}$	12
Weibull Modulus	m	25
Vickers Hardness	HV 0.5	1150
Thermal Expansion Coefficient	$10^{-6} K^{-1}$	10
Thermal Conductivity	W/mK	< 2
Thermal Shock Resistance	ΔT °C	280

Maximum Use Temperature	°C	1000
Volume Resistivity at 25 °C	Ωcm	$>10^{10}$
Dielectric Strength	kV/mm	-

Cerazur **Z-1000** **ZTA**

Electrically insulating, good corrosion resistance, relatively low operating temperature (1000 °C), structural ceramics, good mechanical characteristics, e-module similar to steel (bonding and coatings possible), thermal expansion similar to steel, low thermal conductivity (heat insulator), improved impact resistance, good thermal shock resistance, low specific weight.

Technical Parameter

Description	Unit	Value
Material		ZrO_2 Y-PSZ
Colour		white
Density	g/cm^3	6
Flexural Strength	MPa	1000
Compressive Strength	MPa	3000
Modulus of Elasticity (young)	GPa	205
Impact Resistance	MPa $m^{1/2}$	8
Weibull Modulus	m	22
Vickers Hardness	HV 0.5	1300
Thermal Expansion Coefficient	10^{-6} K^{-1}	10
Thermal Conductivity	W/mK	< 2
Thermal Shock Resistance	ΔT °C	270
Maximum Use Temperature	°C	1000
Volume Resistivity at 25 °C	Ωcm	$>10^{10}$
Dielectric Strength	kV/mm	-

Cerazur Z-1000 ZTA

ZTA

Electrically insulating, good corrosion resistance, relatively high operating temperature, structural ceramics, good mechanical characteristics, improved impact resistance, good thermal shock resistance, low specific weight.

Technical Parameter

Description	Unit	Value
Material		$Al_2O_3 + ZrO_2$
Colour		white
Density	g/cm^3	4.1
Flexural Strength	MPa	600
Compressive Strength	MPa	3600
Modulus of Elasticity (young)	GPa	350
Impact Resistance	MPa $m^{1/2}$	7.5
Weibull Modulus	m	18
Vickers Hardness	HV 0.5	1600
Thermal Expansion Coefficient	$10^{-6} K^{-1}$	6.0 - 8.6
Thermal Conductivity	W/mK	18
Thermal Shock Resistance	ΔT °C	320
Maximum Use Temperature	°C	1000
Volume Resistivity at 25 °C	Ωcm	$>10^{13}$
Dielectric Strength	kV/mm	-

BACK TOP

Ti Squared Technologies, Inc.

1305 Clark Mill Road
Sweet Home, OR 97386

Why Use Titanium/Zirconium?

A Remarkable Alloy

Tiadyne® 3510 is a unique titanium base alloy that enjoys attractive properties for a wide range of applications. It exhibits a martensitic microstructure at room temperature after being quenched from 850° (beta transus approximately 635° C). After aging, at 450°C-550°C, the tensile and yield strengths are increased significantly. It also exhibits a low modulus of elasticity, excellent castability, and superplasticity at elevated temperatures. It is readily weldable and machinable before and after hardening.

An Extraordinary Characteristic

An extraordinary characteristic of Tiadyne 3510 is the capability of being surface hardened by oxidation to a depth that produces very high wear resistant. The hardened layer is very adherent rendering it excellent for articulating parts. The primary elements in the alloy, which are titanium, zirconium, and niobium, are all non-toxic and noncarcinaginic. It is produced by traditional metallurgical processing, requiring no special costly treatments, and is available from Teledyne Wah Chang in all mill forms.

Forgeability and Castability

Tiadyne 3510 is very amenable to hot or warm forging, particularly closed die forging. Sharp corners, indentations, and other details can be accurately produced. This is made possible by the fact that the alloy exhibits superplasticity at about 1350°F. Excessive oxidation during forging can be eliminated or greatly reduced by the use of metal Guard101*. Tiadyne3510 exhibits excellent detailed reproduction in investment castings. No appreciable segregation is present and surface quality is very good.

Chemical Composition (Typical)	
Element	**Weight %**
Carbon	0.004-0.006
Oxygen	0.07-0.13
Hydrogen	0.0015-0.003
Nitrogen	0.0015-0.003
Zirconium	35.0-35.5
Niobium	10.0-11.0
Titanium	Remainder
Density	
5.25 gm/cm	0.1889 lb/cu. in.

Comparison of Properties - Zirconium Alloys v.s. Other Materials

Ti Squared Technologies, Inc., 1305 Clark Mill Rd., Sweet Home, OR 97386
(541) 367-2929, (541) 367-2950(F)

Property		TiZr 3510	Zr-2.5 Cb	17-4	410 S.S.	316 S.S.	AZ91E	A-357	S.T. 21	IN718	Monel S
Mass	Strength to Weight Ratio (Ti6Al-4V=1)	1.1	0.3	0.7	0.3	0.1	0.3	0.5	0.3	0.5	0.4
	Density gm/cc	5.3	6.6	7.6	7.6	8.0	1.8	2.7	8.3	8.3	8.3
	Density lbs/in3	0.19	0.237	0.28	0.28	0.29	0.07	0.1	0.3	0.3	0.3
Thermal Properties	Melting Pt. (deg.F)	3300	3350	2600	2700	2500	950	1300		2550	2400
	Linear Coefficient of Thermal Expansion (.000001in/in/F)	5.9	3.2	6.9	6.1	9	17.4	14.4	8	8	9
	Thermal Conductivity (BTU/hr/sq.ft/Ft/F)		145	9.6	14.4	9	30	70	100		
Mechanical Properties	UTS-ksi	165	64	180	95	65	34	50	101	145	110
	0.2%YS-ksi	160	50	150	75	25	16	40	78	110	80
	%E	14	23	6	8	25	3	5	8	5	1
	HRC	70	8	33		<0	<0	<0	30	21	22

	Young's Mod. (1 million psi)	10.4		28	29	28	6.5	10.5	36	23	26
	Charpy (ft - lb)						3			230	70
	Fatigue ksi at 7 mil.cycles	70					14	13		80	40
Corrosion Resistance Seawater	1 = <.01 mpy										
	10 = .1 mpy										
	100 = 1.0 mpy	1	1	20	120	6	70	170			
Maximum Operating Temp. deg.F		750	750				R.T.	150	2100	1800	
		Zirconium			Steels		Magnesium	Aluminum	Cobalt	Nickel	Ni-Copper
Conversion Key:		1Mpa = .145 ksi			g/cc = .0361 lbs/cu.in.			F = 1.8C + 32		1mm = .039 in.	

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›le 3 Magnetic phase transition temperatures of metallic elements

›ical ɫ	Atomic number	Allotrope	Phase transition temperature (T_c), K	Type of magnetic ordering(a)	Phase transition temperature (T_{c2}), K	Type of magnetic ordering(a)	Phase transition temperature (T_{c3}), K	Type of magnetic ordering(a)	Saturation magnetic moment, μB
›)	58	β-dcph	13.7	AC?	12.5	AC?	...	...	2.61
		γ-fcc	14.4	AC?	...	...	...	...	...
	96	α-dcph	52	AC	...	...	...	...	...
	27	fcc	1388 (1115 °C)	FM	...	...	...	...	1.715
	24	bcc	312.7 (39.5 °C)	AI	...	...	...	...	0.45
	66	α-cph	179.0	AI	89.0	FM	...	...	10.33
	68	cph	85.0	AI	53	AC	20.0	CF	9.1
	63	bcc	90.4	AC	...	...	...	...	5.9
	26	α-bcc	1044 (771 °C)	FM	...	...	...	...	2.216
		γ-fcc	67	AC	...	...	...	...	0.75
	64	α-cph	293.4 (20.2 °C)	FM	...	...	...	...	0.75
	67	cph	132.0	AI	20.0	CF	...	...	10.34
	25	α-bcc	100	AC	...	...	...	...	(d)
	60	α-dcph	19.9	AI	7.5	AC	...	...	1.84
	28	fcc	627.4 (354.2 °C)	FM	...	...	...	...	0.616
	61	α-dcph	98	FM?	...	...	...	...	0.24
	59	α-dcph	0.06	AC	...	...	...	...	0.36
	62	α-rhomb	106	h, A(e)	13.8	c, A(e)	...	...	0.1
	65	α-cph	230.0	AI	219.5	FM	...	...	9.34
	69	cph	58.0	AI	40–32	FI	...	...	7.14

M, transition from paramagnetic to ferromagnetic state; AC, transition to periodic (antiferromagnetic) state that is commensurate with the lattice periodicity (e.g., spins on three atom layers ted up followed by three layers down, etc.); AI, transition to periodic (antiferromagnetic) state that is generally not commensurate with lattice periodicity (e.g., helical spin ordering); CF, tran- ı to conical ferromagnetic state (combination of planar helical antiferromagnetic plus ferromagnetic component); and FI, transition to ferromagnetic periodic structure (unequal number of up lown spin layers). (b) Ce exists in five crystal structures, two of which are magnetic (γ-fcc; and β-dcph). γCe is estimated to be antiferromagnetic below 14.4 K by extrapolation from fcc Ce-La s. (αCe does not exist in pure form below ≈100 K.) βCe is thought to exhibit antiferromagnetism on the hexagonal lattice sites below 13.7 K and on the cubic sites below 12.5 K. (c) Magnetic ›urements quoted in table for γFe are for fcc Fe precipitated in copper. (d) The magnetic moment assignments of Mn are complex. (e) h, A; c, A; indicate that sites of hexagonal and cubic point netry order antiferromagnetically, but at different temperatures. Source: J.J. Rhyne, *Bull. Alloy Phase Diagrams*, Vol 3 (No. 3), 1982, p 402

.y films, while absorption of x-rays by lead ‹es possible its use as a shielding material. thermal-neutron cross section of a metal de- ·s the extent to which that metal absorbs ther- ! (slow) neutrons from a nuclear reactor, and low thermal-neutron cross section of zirco- m makes it a good canning material for nu- ar fuel.

.emical Properties of Metals

:'he chemical property most important to struc- ıl use of a metal is its corrosion behavior. st metals are basic in chemical behavior (will :t with acids). But as stated above, because of chemical activities of the metallic elements, ı oxides rapidly form on freshly bare surfaces nost metals. Ruthenium, rhodium, palladium, ›er, osmium, iridium, platinum, and gold are exceptions. These eight metals have such low :mical activity that they are called *noble met-*

'he physical and chemical properties of the des that form on the nonnoble metals, how- r, differ from metal to metal. Physically, some oxides cohere tightly to their base metal, while others readily spall or flake off and expose fresh base metal to the air. Also, some oxides are very dense and impervious to diffusion and allow very little oxygen to penetrate to the base metal, while others are quite porous and allow oxidation of the base metal to readily continue.

The oxides also differ in their chemical behavior, and this affects their compatibility with various environments (including paints). Many of these oxides are also basic in chemical behavior. The oxides of the alkali metals are strong bases, while those of the alkaline earth metals are moderately strong bases. The oxides of the metals in group 13 of the periodic table, such as aluminum, are amphoteric (react with both strong acids and bases). The oxides of most transition elements are weak bases, but many of these are amphoteric. This includes ferric oxide (Fe_2O_3), which may react with strong bases. In general, the metals farther to the right of the periodic table form oxides that are increasingly weaker bases. While the metal oxides are protective in many situations, it also should be noted that most bare structural metals are very chemically active, and whenever their protective oxide film breaks down, the reaction to the environment can be quite rapid.

General Corrosion Behavior of Metals

The general corrosion behaviors of several metals used in construction are discussed below. More detailed information on corrosion characteristics can be found in the Sections of this Handbook that deal with these metals and their alloys.

ble 4 Room-temperature magnetic sceptibilities for paramagnetic and ımagnetic mat rials

Paramagnetics		Diamagnetics	
'erial	Susceptibility X_m (volume) (SI units)	Material	Susceptibility X_m (volume) (SI units)
'ninum	2.07×10^{-5}	Copper	-0.96×10^{-5}
›mium	3.13×10^{-4}	Gold	-3.44×10^{-5}
lybdenum	1.19×10^{-4}	Mercury	-2.85×10^{-5}
um	8.48×10^{-6}	Silicon	-0.41×10^{-5}
ıium	1.81×10^{-4}	Silver	-2.38×10^{-5}
onium	1.09×10^{-4}	Zinc	-1.56×10^{-5}

Table 5 Mechanical properties of selected metals at room temperature

Metal	Young's modulus (*E*), GPa	Shear modulus (*G*), GPa	Poisson's ratio, ν	Yield strength, MPa	Tensile strength, MPa	Elongation, %
Aluminum	67	25	0.345	15–20	40–50	50–70
Beryllium	303	142	0.07	262–269	380–413	2–5
Cadmium	55	19.2	0.43	...	69–83	50
Chromium	248	104	0.210	...	83	0
Cobalt	211	80	0.32	758	945	22
Copper	128	46.8	0.308	33.3	209	33.3
Gold	78	27	0.4498	...	103	30
Iron	208.2	80.65	0.291	130	265	43–48
Lead	26.1	5.6	0.44	9	15	48
Magnesium	44	16.3	0.35	21	90	2–6
Molybdenum	325	260	0.293	200	600	60
Nickel	207	70	0.31	59	317	30
Niobium	103	37.5	0.38	...	585	5
Silver	71.0	26	0.37	...	125	48
Tin	44.3	16.6	0.33	9	...	53
Titanium	120	45.6	0.361	140	235	54
Tungsten	345	134	0.283	350	150	40
Zinc	69–138	...	...	...	...	...
Zirconium	49.3	18.3	0.35	230	...	32

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Hafnium

Density	13.09 g/cm^3
Thermal Conductivity @ 0°C	0.0533 cal/(s/cm/°C)
Specific Heat @ 25°C	0.035 cal/g
Heat of Fusion	32.4 cal/g
Latent Heat of Fusion	
Heat of Vaporization	155 kcal/g-atom
Latent Heat of Vaporization	
Atomic Volume	13.6 W/D
First Ionizaton Energy	127 kcal/g-mole
Electronegativity	1.3 Paulings
Covalent Radius	1.44 Angstroms
Brinell Hardness	
Mohs Hardness @ 20°C	
Vickers Hardness @ 20°C	
Linear CTE @ (RANGE)°C	5.9 x 10^{-6}
Electrical Resistivity @ 0°C	35.1 µohm/cm
Electrical Conductance	
Crystal Structure	Hexagonal
Curie Temperature	
Modulus of Elasticity	19.8 x 10^6 psi
Youngs Modulus	
Thermal Neutron Cross-section	105 barnes/atom
Magnetic Moment	
Magnetic Susceptibility @ 20°C	

Tensile Strength	86000 psi
Yield Strength	
Electron Work Function	
Vapor Pressure @ 2007°C	10^{-9} atm
Poisson Ratio	
Shear Modulus	
Critical Temperature	
Transformation Temperature	
Critical Pressure	
Standard Electrode Potential	
Ionization Potential	
Compressability	
Thermionic Work Function	
Debye Temperature	
Yield Point	
Hall Consatant	

Zirconium Alloy Data Sheet

FLOWSERVE

Description

Zirconium is used in services too severe for stainless steels, nickel alloys, and titanium or where a significant improvement in service life can be achieved by choosing zirconium instead of less expensive metals or plastics.

When zirconium is chosen for an application, the high cost and expected serviceability require the chemical composition, mechanical properties, and overall casting quality be precisely controlled. Our past record shows that Flowserve meets these criteria so the full benefits of using zirconium can be realized.

Specifications

Flowserve produces two grades of zirconium castings that conform to ASTM Specification B752, Grades 702C and 705C.

Composition

Element	702C %	705C %
Carbon	0.1 max.	0.1 max.
Hafnium	4.5 max.	4.5 max.
Hydrogen	0.005 max.	0.005 max.
Iron	0.3 max.	0.3 max.
Nitrogen	0.03 max.	0.03 max.
Oxygen	0.25 max.	0.3 max.
Phosphorous	0.01 max.	0.01 max.
Niobium	–	2.0 - 3.0
Other elements (total)	0.40 max.	0.40 max.
Zirconium	Balance	Balance

Mechanical and Physical Properties

	702C	705C
Yield Strength, psi (MPa)	40,000 (276)	50,000 (345)
Tensile Strength, psi (MPa)	55,000 (379)	70,000 (483)
Elongation, percent in 1 inch	12	12
Brinell Hardness, 3000 kg max.	210	235
Modulus of Elasticity, psi x 10^6	14.4 x 10^6	14.0 x 10^6
Coefficient of thermal expansion per °C (25°C)	5.89 x 10^{-6}	6.3 x 10^{-6}
Thermal conductivity Btu-ft/hr-ft^2-°F	13	10
Density, lb/in^3/(g/cc)	0.235 (6.51)	0.240 (6.64)
Melting point, °F (°C)	3365 (1852)	3344 (1840)

Corrosion Resistanc

No metal or alloy is resistant to corrosive attack in all chemical environments. Zirconium is no exception, but it does have excellent resistance to a wide variety of chemicals. Zirconium has outstanding resistance to hydrochloric acid, sulfuric acid, organic acids, and alkaline media such as sodium hydroxide. Its resistance to nitric acid is equalled only by the noble metals such as tantalum.

The most common application areas for cast zirconium equipment are in hydrochloric acid, sulfuric acid, and hot organic acids. Zirconium shows excellent corrosion resistance to all concentrations of hydrochloric acid even at temperatures exceeding the normal boiling point. However, zirconium is not resistant to hydrochloric acid containing oxidizing species such as cupric chloride, ferric chloride, or wet chlorine. Zr 702C is resistant to sulfuric acid concentrations up to 70 percent and Zr 705C is resistant to concentrations up to 55 percent to the normal boiling point of sulfuric acid. Poor resistance is obtained with higher concentrations, even at room temperature.

Zirconium is superior to stainless steels, nickel alloys, and titanium in organic acids. This alloy is considered for these applications at high temperatures where its marked superiority results in a distinct economic advantage. Zirconium has poor resistance to concentrated sulfuric acid, hydrofluoric acid, concentrated phosphoric acid, ferric chloride, cupric chloride, wet chlorine, and other oxidizing chloride environments.

Casting Quality

Flowserve zirconium castings are routinely tested and inspected to ensure that optimum casting quality is maintained. Chemical analysis is performed on each melt to verify conformance to published alloy composition.

Weldability and Heat Treatment

Weld repair is performed but must be done in an inert gas atmosphere to prevent oxidation of the weld and heat affected zone. All welds are closely examined for evidence of serious contamination. Insufficient shielding can be readily detected by blue to purple or gray to white colors in the weld whereas silver-bright or straw-yellow colors are indicative of proper shielding during welding. Zirconium castings are not normally heat treated but Zr 702C castings are stress relieved after major weld repair and Zr 705C castings are stress relieved within 14 days of all welds.

Machinability

Zirconium machines to an excellent surface quality and requires low power input compared to steels. However, care must be taken to minimize very fine chips since they are pyrophoric (i.e., may spontaneously ignite in the presence of air). Zirconium does show a tendency to gall and work harden which requires tool clearance angles higher than normal.

Costs

Zirconium is one of the higher priced alloys which find application in the chemical process industry. It is therefore used only where service conditions necessitate its selection. Initial cost of zirconium equipment should be compared to less expensive alternatives only after considering many factors such as the following:

- Zirconium often has far superior corrosion resistance relative to less expensive alternates resulting in greater expected service life.
- Mechanical reliability is often far greater for an alloy such as zirconium as compared to some nonmetallic equipment designs.
- The high cost of production downtime for routine maintenance and equipment failure may require the use of a more reliable, corrosion resistant alloy such as zirconium.

Mechanical Properties

Although Zr 702C possesses good tensile properties, it does have relatively low impact strength compared to most corrosion resistant alloys. However, with proper care zirconium equipment can provide excellent service. Zr 705C offers the user a higher impact strength and, more importantly, a higher pressure temperature limit which could eliminate the need for higher pressure class products. For further information refer to the IOMs (Installation and Operation Manuals) or contact Flowserve's Materials Engineering Department at (937) 226-4000.

FLOWSERVE™

ServiceRepair Division

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The Table of Modulus of Elasticity about Metal

±Ý ¼Ó Metal		Ã¼ÀûÅº¼ºÂè¼ö K [kgf/cm^2]	Åº¼ºÂè¼ö E [kgf/cm^2]	°¡Î Åº¼º °è¼ö G [kgf/cm^2]	ÇÁ¿Í¼Û°ñ ν
Li	Lithium	1.39×10^5	1.17×10^5	0.43×10^5	0.36
Na	Sodium	0.83×10^2	0.91×10^2	0.35×10^2	0.32
K	Potassium	0.41×10^2	0.36×10^2	0.13×10^2	0.35
Be	Beryllium	1.28×10^3	3.16×10^3	1.50×10^3	0.05
Mg	Magnesium	3.39×10^2	4.52×10^2	1.77×10^2	0.28
Al	Aluminum	7.46×10^2	7.19×10^2	2.72×10^2	0.34
Ti	Titanium	1.26×10^3	1.08×10^3	4.05×10^2	0.34
Zr	Zirconium	9.15×10^2	9.75×10^2	3.68×10^2	0.33
Hf	Hafnium	1.12×10^3	1.41×10^3	5.40×10^2	0.30
V	Vanadium	1.65×10^3	1.30×10^3	4.76×10^2	0.36
Nb	Niobium	1.67×10^3	1.06×10^3	3.73×10^2	0.38
Ta	Tantalum	2.11×10^3	1.88×10^3	7.00×10^2	0.35
Cr	Chromium	1.94×10^3	2.40×10^3	9.00×10^2	0.30
Mo	Molybdenum	2.80×10^3	3.47×10^3	1.22×10^3	0.30
W	Tungsten	3.19×10^3	3.96×10^3	1.51×10^3	0.29
Mn	Manganese	1.27×10^3	2.02×10^3	7.80×10^2	0.24
Fe	Iron	1.72×10^3	2.17×10^3	8.47×10^2	0.28
Co	Cobalt	1.87×10^3	2.04×10^3	7.63×10^2	0.31
Ni	Nickel	1.87×10^3	2.05×10^3	7.85×10^2	0.31
Cu	Copper	1.40×10^3	1.25×10^3	4.64×10^2	0.34
Ag	Silver	1.02×10^3	8.05×10^2	2.94×10^2	0.38
Au	Gold	1.75×10^3	8.02×10^2	2.82×10^2	0.42
Zn	Zinc	6.17×10^2	9.40×10^2	3.79×10^2	0.29
Cd	Cadmium	4.85×10^2	6.35×10^2	2.46×10^2	0.30
In	Indium	4.45×10^2	1.07×10^2	0.38×10^2	0.46
Tl	Thallium	3.71×10^2	0.81×10^2	0.28×10^2	0.46
Si	Silicon	3.22×10^3	1.15×10^3	4.05×10^2	0.44
Ge	Germanium	7.11×10^2	1.01×10^3	4.00×10^2	0.28
Sn	Tin	5.20×10^2	5.54×10^2	2.08×10^2	0.33
Pb	Lead	4.22×10^2	1.66×10^2	0.57×10^2	0.44
Sb	Antimony	4.00×10^2	5.60×10^2	2.04×10^2	0.28
Bi	Bismuth	3.60×10^2	3.48×10^2	1.31×10^2	0.33

Reference : W. Köster and H. Franz : Metallurgical Review, 6 (1961)

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gigapascal

Symbol:	GPa
Category:	Pressure
SI Equivalent:	1×10^{9} Pa
Dimension:	$ML^{-1}T^{-2}$
System:	SI

Download a Palm version of this unit conversion calculator!

Convert 96.527 **GPa**

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Pressure

	Symbol	Unit Name
9.52647×10^{5}	atm	atmosphere (standard)
9.6527×10^{5}	**bar**	**bar**
7.24012×10^{7}	cmHg (0 °C)	centimeter of mercury (0 °C)
9.84329×10^{8}	cmH_2O	centimeter of water (4 °C)
9.6527×10^{11}	dyn/cm^2	dyne per square centimeter

3.22943×10^7	**ft H_2O**	**f t f water (4 °C)**
2.85044×10^7	inHg (0 °C)	inch of mercury (0 °C)
3.879×10^8	inH_2O (15.56 °C)	inch of water (15.56 °C)
9.84301×10^5	**kgf/cm^2**	**kilogram force per square centimeter**
9.84301×10^9	kgf/m^2	kilogram force per square meter
1.40001×10^4	**kip/in^2, ksi, KSI**	**kilopound force per square inch**
9.6527×10^4	**MPa**	**megapascal**
9.6527×10^8	mbar	millibar
9.6527×10^{10}	Pa, N/m^2	pascal
2.01601×10^9	lbf/ft^2	pound force per square foot
1.40001×10^7	**psi, PSI, lbf/in^2**	**pound force per square inch**
7.24012×10^8	**torr**	**torr**

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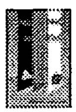
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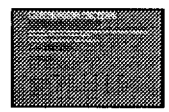
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